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~~[Preprint]~~

by

S. N. Vernov
V. V. Mel'nikov
I. A. Savenko
B. I. Savin

[USSR]

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MEASUREMENTS OF LOW ENERGY PARTICLE FLUXES ON SATELLITES "COSMOS" AND "ELECTRON" *

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V. V. Mel'nikov,
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SUMMARY

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This paper deals mainly with measurements of particle fluxes with energies 0.1 ÷ 10 kev, conducted with the aid of spherical electrostatic analyzers placed aboard "Electron-2". The data considered cover the period from 30 January through 21 February 1964. Presented here also are the general results of short-term experiments carried out on the satellites "Cosmos-12" and "Cosmos-15".

A description is given of the apparatus, identical for both types of satellites.

The general conclusion derives from measurements of ions during the period consists in that the total flux of ions in the said energy range does not exceed, inside the magnetosphere, the devices' response threshold, that is, $5 \cdot 10^7$ ion/cm^2 sec., result which agrees well with those of Explorers 10, 12 and 18 inside the magnetosphere. author

* * *

When measuring plasma fluxes inside the magnetosphere aboard Soviet and American rockets and satellites, certain data were obtained during the last few years on densities, fluxes and spatial distribution of low energy particles ($\sim$40 kev) near the equatorial plane of the magnetosphere [1 – 6]. The current paper refers to measurements of particle fluxes with energies 0.1 ÷ 10 kev, completed aboard "Electron-2" using spherical electrostatic analyzers [7].

* IZMERENIYA POTOKOV CHASTITS MALYKH ENERGIY NA SPUTNIKAKH "KOSMOS" I "ELEKTRON".

Electron-2 was launched on 30 January 1964 and was operational during a prolonged time in the high-latitude regions of the magnetosphere. The apogee was 11.7 R_E and was at flight commencement at a point with 3.3 hours local time. The perigee of the orbit was 460 km, the revolution period was of 22 hours 40 minutes, the inclination angle of orbital to terrestrial equator plane was 61^o. The data under consideration cover the period from 30 January to 21 February 1964. The spherical analyzers of the construction described were also applied in the short-term experiments carried out on Cosmos-12 and 15, of which a brief compilation of the results obtained is given here.

APPARATUS

The only difference in the electrostatic analyzers used on satellites Cosmos and Electron was in their respective electron circuits. The main part of the analyzer consists in a spherical condensor, to the lining of which symmetrical potentials $+\frac{U}{2}$ and $-\frac{U}{2}$ are fed. The angle of trajectory deflection of a particle, flying in the meridional plane of the condensor is $\sim 125^o$ [8]. The spherical condensor is located inside a thin aluminum casing connected with the satellite frame.

The trajectories of particles received by the analyzer, lie in the interval of angles $\vartheta = 60 \pm 10^o$, where ϑ is the angle between the axis of the deflecting condensor and the trajectory direction of the particle, entering the gap between linings. The analyzer geometrical factor is $G \sim 0.1 E_0$ cm^2 ster kev, the half-width of the pass-band is $(\frac{\Delta E}{E_0})_{1/2} = 15\%$.

A block-diagram of the analyzer of Electron-2 is shown in Fig. 1. The device contained two separate SAL and SAH- analyzers, with the proper electron circuits and the changeover devices.

The SAL-analyzer was tuned to the registration of electrons and positive ions with energies $E_0 = 0.1$; 0.2; 0.5; 1 kev, and was switched from one energy to the other by command from ground, when the satellite was at perigee. The SAH-analyzer was tuned to energies of 1, 2, 5 and 10 kev and was switching over once every two minutes on airborn command. The particles having passed through the analyzer hit the collectro, at whose input two grids were mounted. The nearest one to collector was connected with the frame, while on the other, a — 20 potential relative to frame was sustained. It was verified experimentally that a — 20 potential was sufficient for the suppression of secondary electrons from collector. The grids also weaken the capacitive coupling between collector and spheres.

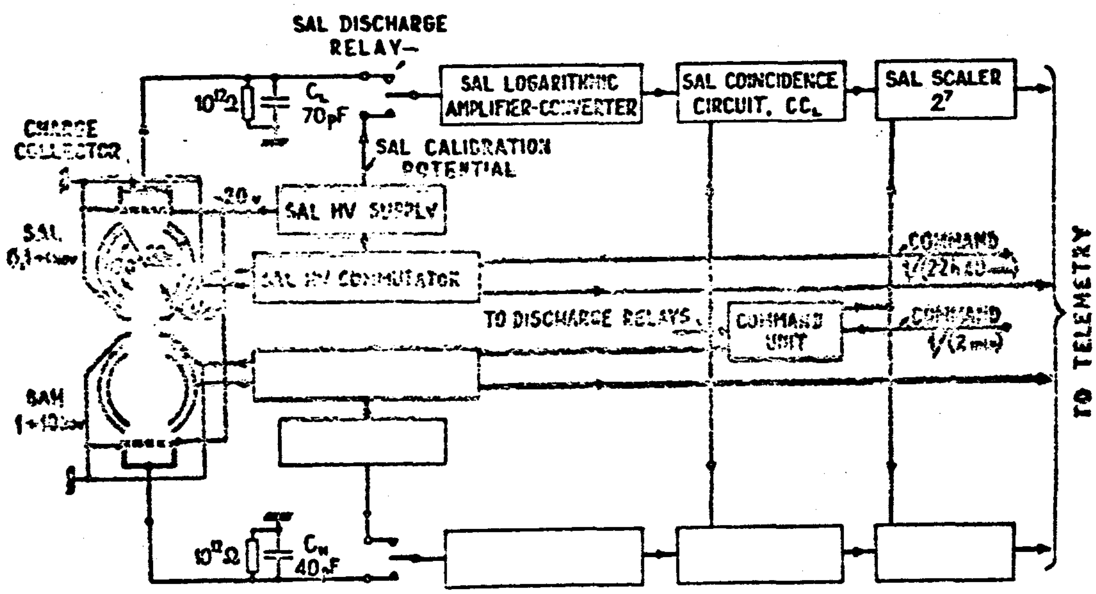

Fig.1. BLOCK DIAGRAM OF „ELECTRON-2" ELECTROSTATIC ANALYZERS

For the measurement of collectro current, the principle of charge accumulation on the condensor was applied, together with its logarithmic conversion into a number of pulses [9]. Every cycle of analyzer operation began from the arrival of airborne command to the master block of the device, and lasted 120 sec.

The master block formed three consecutives pulses, the first of which being utilized for setting all the triggers in the state "0". The second pulse was used to close the discharge relays of the SAL and SAN condensors, and was simultaneously fed to coincidence circuits od same. The series of pulses appearing at logarithmic conversion circuit output at closing of discharge relay were counted by trigger chains. The third pulse switched over the SAN-analyzer's high-voltage commutator.

All the changeovers ended by $\sim \frac{1}{2}$ sec after arrival of the airborne command, and subsequently charge accumulation began on condensors SAL and SAN. The duration of a cycle is 120 sec. or 480 sec on some convolutions. The conditions of triggers were interrogated prior to arrival of airborne command. At every 18th cycle the discharge relays were switched to control condensors and not the measuring ones, the former being charged to a rather low voltage spheres' feeding sources. The minimum particle flow J_{min}, average in the interval ΔE, registered by the analyzer, constitutes in the assumption of isotropy, $\sim 1 \cdot 10^7 \frac{I}{E_o}$ particle / cm^2·kev.

RESULTS

"COSMOS-12","COSMOS-15" [10, 11]. - The electrostatic analyzers of these satellites were tuned to the registration of electrons and ions with energy of 1 kev. Their orbits passed at distances of 405 — 173 km from the Earth's surface; the orbit planes were inclined at 65° to the plane of the terrestrial equator. The analyzer readings usually did not exceed their threshold of response, that is $\sim 1 \cdot 10^7$ particle/cm^2 sec kev. at 180 $\pm$ 30° E.L., 60 — 65° S.lat., region of the South of New Zealand, where passes the maximum isochasm, a region of intensity increase of electrons was revealed. - At every flight through that region electron fluxes to $2 \cdot 10^8$ electron/cm^2 sec kev were registered, whenever data on analyzer operation were available. Data on particle fluxes in that region were obtained from two flights of Cosmos-12 on 28 December 1962 and from four flights of Cosmos-15 on 23, 24 and 25 April 1963.

"ELECTRON-2".- PERIOD FROM 30 JANUARY THROUGH 21 FEBRUARY. - At each convolution the satellite passed through the region of increased intensity of electrons with energies 0.1 — 10 kev over the ascending, as well as descending portions of the trajectory, or over one of them. These portions of trajectory were all located near midnight or 07 00 hours L.T. The examples compiled according to SAL data are plotted in Fig. 2, which is the ascending part of the 19th orbit, and on Fig. 3, which is its descending portion. The SAL-analyzer was tuned, over this orbit, to electrons with energies E_o = 0.5 kev. The SAL-device's readings were converted here from the intensity of the isotropic flux of electrons and corrected for the background. The analysis of the character of readings of the device, including the data on satellite's orientation and own spinning, allowed to establish, that background is conditioned in these areas only by the photocurrent from collector grids. The maximum value of the photoelectron signal was equivalent to the flux of $\sim 1 \cdot 10^8$ particle/cm^2·sec·kev.

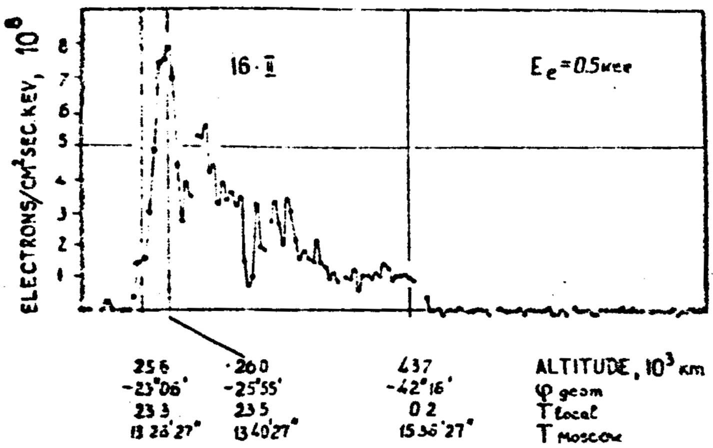

Fig. 2. Example of passage through the region of increased intensity of electrons on the ascending portion of the trajectory of the 19th orbit.

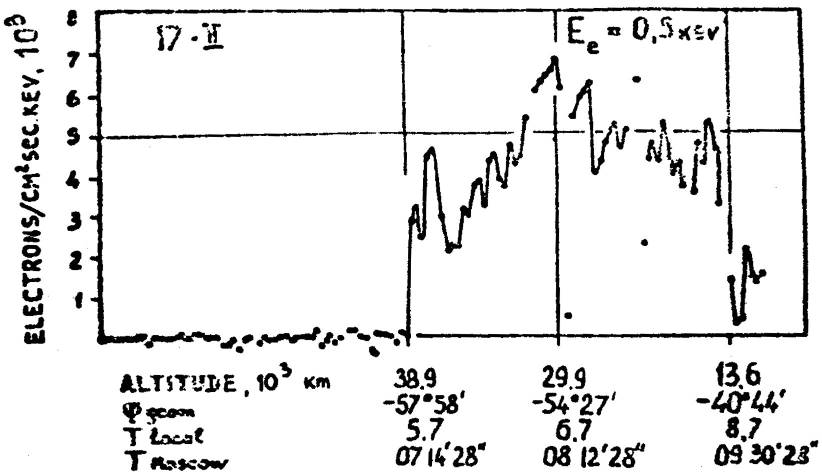

Fig. 3. - Same for the descending portion of trajectory of the 19th orbit.

The variations of the maximum registered intensity of electrons at night morning passages in regions are plotted in Fig. 4. In these regions, the electron fluxes attained the values of $\sim 10^9$ electron/cm^2 sec kev at $E_0 = 0.2$ kev and $\sim 1 \cdot 10^8$ at $E_0 =$ kev. The absolute values of intensity are brought up with a root-mean square error of ±50%. Shown in the same figure is the boundary of the regions of increased intensity of electrons with energies of $1 - 10$ kev, brought up into the magnetic equator plane along the dipole lines of force. For the boundary, the point was chosen, where the intensity of electrons constituted one half of the maximum.

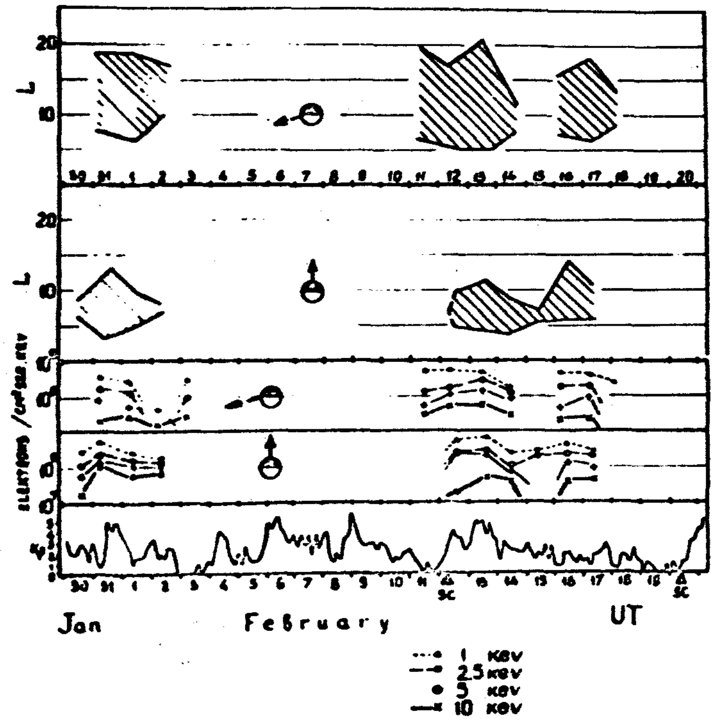

Fig. 4. - Extension of the regions of increased intensity and electron fluxes maximum in the regions. The data are related to electrons with energies from 1 to 10 kev.

On the apogee portions of the orbit, the SAL and SAN analyzers did not, as a rule, register any fluxes exceeding the threshold of response. However, at certain flights in the apogee region sporadic rises in the intensity of electrons with energies $E_0 \lesssim 1$ kev were observed. At first such rises were noted over the descending portion of the trajectory of the 14th orbit on 12 February, and registered from 08 20 to 09 20 hours UT by the SAL- analyzer, tuned up for electrons with energies of 1 kev. The flux of such electrons attained $1.5 \cdot 10^8$ electrons/cm$^2 \cdot$ sec $\cdot$ kev.

The appearance of a sporadic flux of electrons with energy of 200 kev was also noted on 19 and 20 February. While on the 19th the value of the flux did not exceed $1 \cdot 10^8$ el/cm^2 sec kev, on the 20th it became greater than $1 \cdot 10^9$ electron/cm^2 sec kev. Data for the 18th show that this sporadic flux began apparently already on that day, but its intensity was less than $1 \cdot 10^8$ electron/cm^2 sec kev. The readings of the SAL-analyzer for 19 and 20 February are compiled in Fig. 5 and 6. The corrections for the photoelectron signal were not effected in Fig. 6. The coordinates of trajectory portions, where sporadic fluxes were registered, are shown in the Table hereafter :

TABLE

DATE	BEGINNING OF REGISTRATION				END OF REGISTRATION		
	Height thous. km	Geomag. lat.	L.T.		HEIGHT thous. km	Geomag. lat.	L. T.
12 Febr.	56.9	-49.5°	4.2		51.9	-50°	4.7
19 Febr.	64.6	-53.4°	1.1		63	-71.6	4
20 Febr.	67	-54.8°	1.4		68	-61°	2

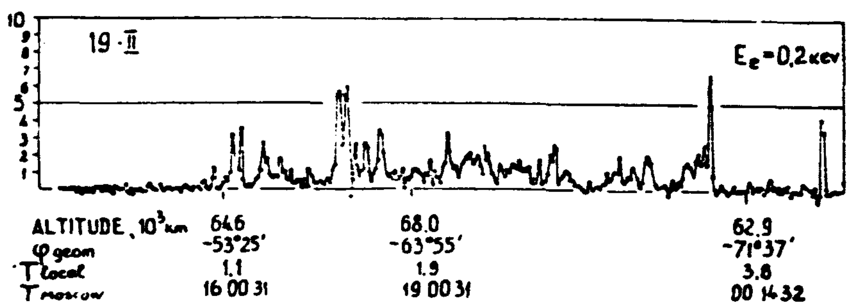

Fig. 5. - Example of detection of the sporadic layer of electrons on 19 February.

The readings of the SAL and SAN analyzers never exceeded the background level when tuned on the ions. Only on 1 — 3 February and 6 — 7 February orbits could the character of analyzer SAL readings be linked with the registration of ion fluxes with energy of 100 — 200 ev and intensity of several units of $10^7 \cdot \frac{I}{E_0}$ ion/cm^2 sec kev.

DISCUSSION

The apogee of Electron-2 was distant from the center of the Earth by 11.7 R_E and was located at the commencement of flight at ~0300 hours LT.- The readings of the airborne magnetometer, just as the existing representations of the structure and dimensions of the magnetosphere, suggest that Electron-2 did not fly beyond the magnetosphere boundary. All cases of electron detection by analyzers are subdivided into two groups. The first group refers to regions of increased intensity at moderate heights, while the second corresponds to sporadic fluxes over apogee portions of orbit.

The electron fluxes in the regions of increased intensity were registered on all convolutions during the considered time period. The intensity of electrons varied from convolution to convolution by several times. Analysis of spatial disposition of trajectory portions, over which the satellite passed through these regions, shows, that the difference in the intensity over various flights cannot be fully explained by trajectory displacement. Moreover, during the time from 10 to 14 February, the trajectories of the satellite during flights through the regions practically coincided; however, the intensity of electrons was low at the beginning, and increased after the storm of 12 February.

Consideration of the graphs, similar to indications of Fig .2 and 3, leads to the conclusion, that the fluxes of electrons in the regions are not endowed with a sharply expressed course, which ought to manifest itself in a form of curve modulation on account of satellite
place with a period somewhat smaller than 120 sec. A weak modulatinn can be perceived with a period of a few cycles; however, this modulation is much rather linked with the inaccuracies of corrections for background. Data on the position of the regions of increased intensity of electrons, brought out in Fig. 4, show, that on the night side the region is situated between $L \sim (3 \div 7)$ and $L \sim (7 \div 13)$, on the morning side between $L \sim (10 \div 14)$ and $L \sim (12 \div 20)$. The outer boundary of the morning region is much sharper, as a rule, than that of the night region. It may be seen from Fig. 4 that the electrons, populating the regions, are observed in

magnetoquiet, as well as in mag to-disturbed days, but the extension of the regions and the intensity of electrons in them positively correlate with the K_p- index. The spectrum of electrons in the regions reveals a tendency to softening at drifting from Earth.

Represented in Fig. 7 are the regions of increased intensity of low energy electrons after the data of analyzers from Electron-2, and also the regions, in which electrons with energies $>$ 200 ev. were detected during the flights of the 2nd Soviet cosmic rocket [1], of the "Mars-1" probe and "Explorer-12" [4]. The position of the magnetosphere boundary in the equatorial plane after the data from Explorer-18 are also plotted in Fig. 7 [5]. Comparison of data on the night side shows, that the results of measurements on Electron-2 agree well with the earlier experiments. The night region of increased intensity of low energy electrons, registered by the analyzers of Electron-2 during a prolonged time and high geomagnetic latitudes, constitutes apparently a branch of the so-called "outermost" radiation belt. The region of increased intensity of electrons on the morning side and high geomagnetic latitudes, was at first observed during the flight of Electron-2, as far as we know. It should be noted, that during the flight of Explorer-12 no increase in intensity of electrons with energy $>$ 200 ev was observed on the morning side near the equatorial plane. The existence of the morning electron region, revealed by Electron-2 at high latitudes, can be related to processes taking place near the neutral points of the magnetosphere.

The sporadic fluxes of electrons are characterized by fairly large and rapid oscillations of intensity and are registered between midnight and morning meridians beyond the above-considered regions. The electrons of sporadic fluxes are apparently situated on the lines of force of magnetosphere tail. It was noted that after the appearance on 12 February of the sporadic flux, the extension of the regions of increased intensity of electrons with energy from 1 to 10 kev increased. Strongly increased also was the extension of the electron region with energy of 0.2 kev after detection of the sporadic flux of 20 February. Attention should be drawn also to the fact that on 12 and 20 February, SC magnetic storms were observed and registered. These facts point to a possible link between the appearance of sporadic flux , geomagnetic disturbances and the population of regions of increased intensity of electrons.

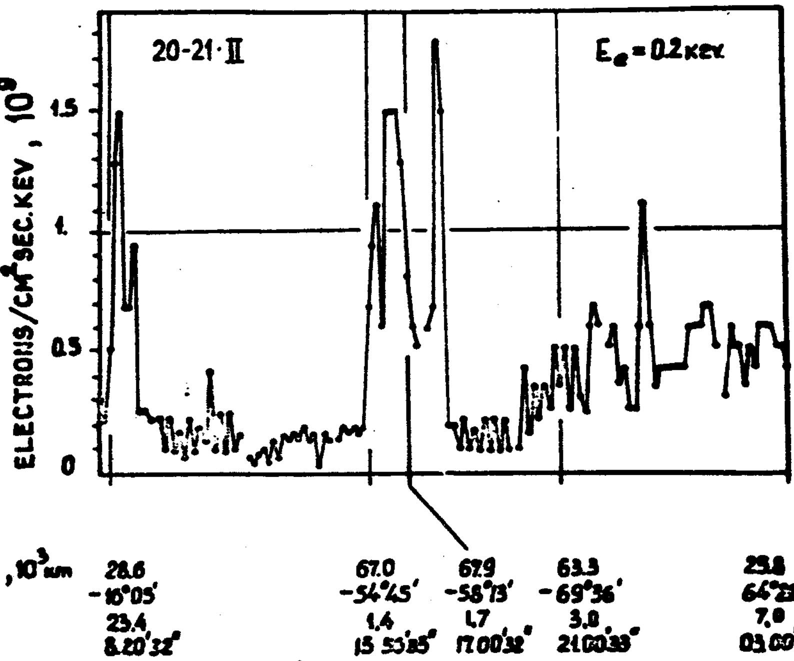

Fig. 6. - Example of detection of the sporadic flux of electrons on 20 February.

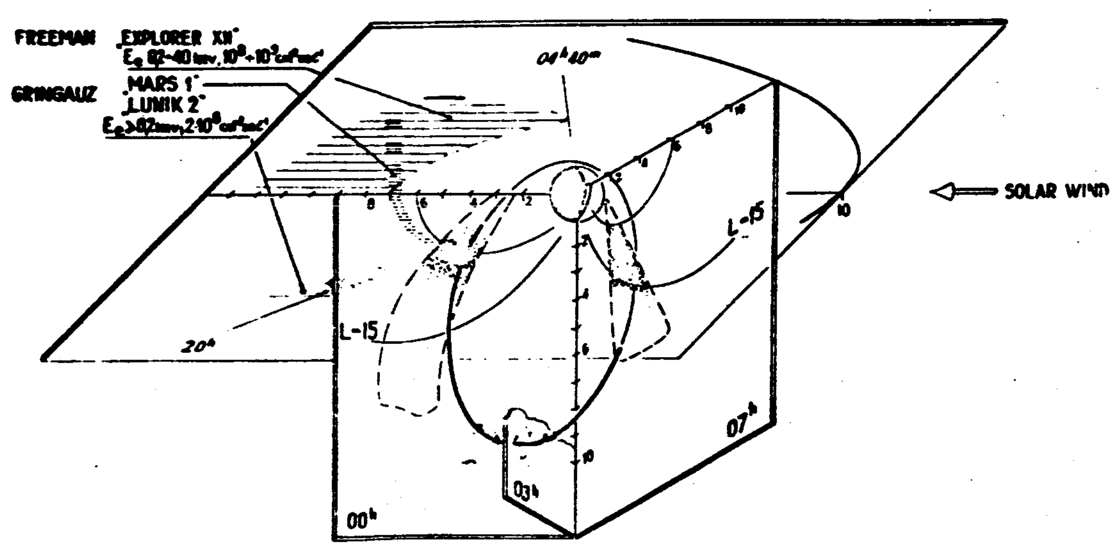

Fig. 7. - Comaprison of earlier re lts of mea rements of low energy electron fluxes with the data obtained with the aid of electrostatic analyzers of the satellite Electron-2.

The general conclusion derived from measurements of ions for the period from 30 January through 20 February 1964 consists, in our opinion, in that the total flux of ions in the energy interval 0.1 — — 10 kev inside the magnetosphere does not exceed the threshold of response of devices, that is, $\sim 5 \cdot 10^7$ ion/cm^2·sec.

This conclusion agrees well with the results of measurements of ions on satellites Explorer-10, -12, -18 inside the magnetosphere. According to data of Explorer-10 trap, ion fluxes, during a single flight and at $R > 3.9\,R_E$, did not exceed $3 \cdot 10^7$ ion/cm^2·sec. [2].A spherical electrostatic analyzer was installed aboard Explorer-12 for measurement of ions [3].- According to the data from the latter, the isotropic flux of ions did not exceed $2 \cdot 10^9$ ion/cm^2·sec in the energy interval from 0.1 to 20 kev. The trap of the satellite Explorer-18 [5] failed to reveal ion fluxes exceeding 10^8 ion/cm^2 sec. in the 45 — 5400 ev energy range.

**** THE END ****

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